CURE COURSE SYLLABUS

Course title and number: Tentative title: Biomaterials and Medical Device Design
Term: Tentative
Meeting times and location: Tentative

Instructor Information

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Course Description: This 3-credit course introduces students to the field of biomaterials and medical devices through a Course-Based Undergraduate Research Experience (CURE) framework. Students will explore the materials science of metals, polymers, and biological materials used in medical applications while engaging in authentic, research-driven inquiry centered on real clinical challenges.

The course is organized into four device-focused modules:
Module 1: Hard Tissue Devices - Total Hip Replacements (Material focus: Metals)
Module 2: Hard Tissue Devices - Total Hip Replacements (Material focus: Polymers)
Module 3: Soft Tissue Devices - Breast Implants
Module 4: Blood-Contacting Devices - Artificial Vascular Grafts

Within each module, students will collaboratively explore research questions that may lead to novel design insights or hypotheses for improved device performance. Using discipline-based research methods, including primary literature analysis, materials characterization principles, failure analysis, and design evaluation, students will investigate how biomaterials interact with biological systems and why devices succeed or fail in clinical settings.

Each module will include:
- Analysis of the design, structure, properties, and failure modes of natural tissues
- Evaluation of clinically used implant and tissue replacement strategies
- Investigation of material, structural, and mechanical design consideration
- Critical assessment of clinical outcomes and device performance
- Identification of material- and design-related failure mechanisms
- Development of evidence-based proposals for improved or alternative device designs

Students will engage in iterative research cycles that include literature review, hypothesis development, structured design critique, and revision based on feedback. Collaboration will be central to the course. Students will work closely with the instructor and, in many cases, with peers to formulate research questions, interpret data, and refine design proposals. Final outcomes may include research-style reports, design briefs, or white-paper proposals intended to mirror contributions to the broader scholarly and biomedical engineering community. Through this CURE-based approach, students will not only learn foundational biomaterials principles but also actively participate in the process of discovery, applying engineering analysis to address unresolved challenges in medical device design.

Prerequisites: N/A. Basic knowledge of materials, human anatomy/physiology, and engineering principles.
Audience: Upperclassman undergraduate and graduate students who are interested in the concepts of the field of biomaterials engineering and medical device development.
Credits: 3
Course Fees and/or Costs: N/A

Learning Outcomes: By the end of this CURE-based course, successful students will be able to:
- Explain and apply the relationship between material structure, material properties, and material performance in the context of clinically used medical devices

- Analyze and interpret failure modes of medical devices using evidence from primary literature and engineering principles
- Formulate research-informed, materials-based design modifications aimed at improving clinical performance
- Develop and refine research questions related to biomaterials and device design through iterative inquiry and structured reflection
- Communicate design analyses and evidence-based proposals in formats appropriate for scientific and engineering audiences.

Students will engage in shared exploration of open-ended design and research questions, use discipline-based research practices (e.g., literature analysis, failure analysis, and design evaluation), and iteratively refine their ideas through feedback and reflection. Learning will occur through active participation in discussions, collaborative research activities, structured critique, and both independent and team-based assignments.

Bioengineering undergraduate students in this course are expected to meet the following ABET student outcomes:

- **Outcome 1** – An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. (Addressed through analysis of device failures and development of research-driven design solutions.)
- **Outcome 3** – An ability to communicate effectively with a range of audiences. (Addressed through written research-style reports, design briefs, and in-class presentations.)
- **Outcome 5** – An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. (Addressed through collaborative module-based research and design activities.)
- **Outcome 7** – An ability to acquire and apply new knowledge as needed, using appropriate learning strategies (Addressed through engagement with primary literature, independent inquiry, and iterative refinement of design concepts.)

Textbook and Resource Material

- **Textbook:** *electronic full text version available through SU Library*
  Biomaterials Science: An Introduction to Materials in Medicine. 3rd Ed. B.D. Ratner, A.S. Hoffman, F.J. Schoen, and J.E. Lemons (Eds.), Academic Press, 2013.
- **Readings**: Recent research articles and book sections may be posted on Blackboard.
- **Blackboard:** All course content will be posted on Blackboard. Please check regularly.

Grading Policies: All grades for assignments are based out of 100. All assignments within a category are worth the same amount unless otherwise stated.

1. Research development and documentation - 30%

Short homework assignments, structured literature analyses, and in-class applied activities designed to build the conceptual and analytical skills necessary for device investigation. Collaboration is encouraged; however, individual submissions must reflect each student's independent synthesis and understanding. This category integrates research preparation activities with ongoing reflective documentation of the research process.

Students will complete short homework assignments, structured literature analyses, and in-class applied exercises designed to build the conceptual and analytical skills necessary for medical device investigation. In parallel, each student will maintain an individual research notebook documenting:

- Development and refinement of research questions
- Proposed design hypotheses
- Key findings from literature
- Feedback received from peers and instructor
- Revisions made to analyses and design ideas

2. Module-based research briefs - 20%

At the end of each device module, student teams will submit concise research briefs that:

- Identify an unresolved materials or design challenge
- Analyze supporting evidence from primary literature
- Propose a research-informed design modification or hypothesis

- Justify feasibility and potential clinical relevance

3. Exams - 20%
Two exams will assess mastery of foundational biomaterials principles. The exams ensure alignment with ABET Outcome 1 while allowing more course time to focus on research practice.

4. Semester-long device research and redesign project - 30%
Students will work in teams of 4-5 to conduct an in-depth investigation of a clinically used medical device not covered in class. All teams are expected to attend and engage in presentation sessions as part of the collaborative scholarly community.